Report of a workshop on population viability assessment as a tool for threatened species management and conservation

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ABSTRACT

A Population Viability Assessment (PVA) workshop was held in Melbourne in May, 1990, to demonstrate its potential to wildlife managers by applying PVA to six species of threatened wildlife in Victoria. The workshop ran for one week and involved 32 participants, who worked in teams. The computer program VORTEX was used to simulate population behaviour resulting from random demographic, genetic and environmental variation, and catastrophic events. VORTEX runs on an MS-DOS microcomputer, and Toshiba laptop microcomputers plus printers and plotters were used. Simulations were run and analysis of results completed in the week following the workshop. PVA results were used to set management goals and strategies for the species examined. PVA is a useful tool for the management of threatened species for which there are adequate population data, and regular application of the technique is likely in the future. The workshop proved a useful way to demonstrate and apply Population Viability Assessment in a relatively short period of time.

INTRODUCTION

Computer simulation modelling of population processes is a useful approach to understanding the viability of small populations. It enables the quantifiable assessment of outcomes that might be intuitive but otherwise not quantifiable. This aspect is important when competing for resources to undertake species recovery programs.

Population viability assessment is a procedure that allows managers to simulate extinction processes that act on small (generally n<500) populations, and therefore to assess their long-term viability. In both real and simulated populations, a number of interacting demographic, genetic, environmental, and catastrophic processes determine the vulnerability of a population to extinction. These four extinction processes can be simulated in computer models and the effects of both deterministic and random or stochastic forces can be explored. In turn, the outcome of various management options, such as reducing mortality, supplementing the population, and increasing carrying capacity, can also be simulated. Thus, PVA provides managers with a powerful tool to aid in assessing the viability of small populations, and for setting target numbers for species recovery as a basis for planning and carrying out recovery programs. In addition, having performance-based management programs enables quantifiable assessment of progress towards achieving the programs' aims. PVA also offers managers a powerful strategic planning and policy tool, when vying for limited financial resources for threatened species management. This paper describes a PVA workshop which used a stochastic computer simulation to model small populations of six species of threatened wildlife in Victoria and to explore management options to enhance their conservation status.

THE WORKSHOP

The workshop was co-sponsored by the Victorian Department of Conservation and Environment (DCE) and the Zoological Board of Victoria (ZBV), in co-operation with the Chicago Zoological Society (CZS) and was held at the Arthur Rylah Institute for Environmental Research (DCE) from 28 May–1 June 1990. Its objectives were to: 1) examine the adequacy of data on the six threatened species selected; 2) simulate by using PVA their vulnerability to extinction; 3) examine outcomes of various management options to restore the species; 4) estimate population targets needed in recovery planning; 5) evaluate the potential of PVA as a teaching aid to illustrate extinction processes and management options.

The six threatened species examined were: Mountain Pygmy-possum *Burramys parvus*, Leadbeater's Possum *Gymnobelideus leadbeateri*, Eastern Barred Bandicoot *Perameles gunnii*, Long-footed Potoroo *Potorous longipes*, Orange-bellied Parrot *Neophema chrysogaster*, and Helmeted Honeyeater *Lichenostomus melanops cassidix*.

A month prior to the workshop all participants were provided with background reading material including papers by Shaffer (1981), Brussard (1985), Samson (1985), Gilpin (1989), Soule (1989) and Lacy and Clark

(1990). A questionnaire on life-history parameters to be completed on each species as a basis for entering values into the computer model was also provided.

An introduction session to computer simulation using a population simulation program (GRIER) written by James W. Grier of North Dakota State University (Grier 1980a) was run prior to the workshop.

POPULATION VIABILITY ASSESSMENT: THE VORTEX MODEL

The workshop used a computer program, VORTEX, to simulate demographic and genetic events in the history of a population. This program has the capacity to simulate each of the four stochastic processes outlined in the Introduction, and is able to represent the range of pressures to which small populations are vulnerable. VORTEX was written in the C programming language by Robert Lacy for use on MS-DOS microcomputers. Many of the algorithms in VORTEX were taken from a simulation program, SPGPC, written in BASIC by James Grier (Grier 1980a, 1980b; Grier and Barclay 1988). Earlier versions of VORTEX (under the name of SIMPOP) have been used for population viability analyses in the United States (e.g., Lacy *et al.* 1989; Seal and Lacy 1989) and Australia (Lacy and Clark 1990).

Life table analyses yield average long-term projections of population growth (or decline), but do not reveal the fluctuations in population size that would result from variability in demographic processes. When a population is small and isolated from other populations of conspecifics, these random fluctuations can lead to extinction, even in populations that have, on average, positive population growth. Fluctuations in population size can result from several levels of stochastic effects. Demographic variation results from the probabilistic nature of birth and death processes. Therefore, even if the probability of an animal reproducing or dying is always constant, the actual number reproducing or dying within any time interval would vary according to a binomial distribution with mean equal to the probability of the event (p) and variance given by $Vp = p * (1-p)/N$. Demographic variation is thus intrinsic to the population and occurs in the simulation because birth and death events are determined by a random process (with appropriate probabilities).

Environmental variation (EV) is the variation in the probabilities of reproduction and mortality that occur because of changes in the environment on an annual basis (or other timescales). Therefore, EV has an impact on all individuals in the population simultaneously, changing the mean probabilities of the above binomial distributions of birth and death.

VORTEX models population processes as discrete, sequential events, with probabilistic outcomes determined by a pseudo-random number generator. It simulates birth and death processes and the transmission of genes through the generations by generating random numbers to determine whether each animal lives or dies, whether each adult female produces broods of size 0, 1, 2, 3, 4, or 5 during each year, and which of the two alleles at a genetic locus are transmitted from each parent to each offspring. Mortality and reproduction probabilities are sex-specific. Mortality rates are specified for each pre-reproductive age class and for reproductive-age animals. Fecundity is assumed to be independent of age after an animal reaches reproductive age. The mating system can be specified to be either monogamous or polygynous. In either case, the user can specify that only a subset of the adult male population is in the breeding pool (the remainder being excluded perhaps by social factors). Those males in the breeding pool all have equal probability of siring offspring.

Each simulation is started with a specified number of males and females of each pre-reproductive age class and of breeding age. Each animal in the initial population is assigned two unique alleles at some hypothetical genetic locus. The user specifies the severity of inbreeding depression, which is expressed in the model as a loss of viability in inbred animals. The computer program simulates and tracks the fate of each population and then produces summary statistics on: the probability of population extinction over specified time intervals; the mean time to extinction of those simulated populations that went extinct; the mean size of populations not yet extinct; and the levels of genetic variation remaining in any extant populations.

A population carrying capacity, specified by the user, is imposed by a probabilistic truncation of each age class if, after breeding, the population size exceeds the specified carrying capacity. The program allows the user to model trends in the carrying capacity as linear increases or decreases across a specified number of years.

VORTEX models environmental variation simplistically (which is both an advantage and disadvantage of simulation modelling), by selecting at the beginning of each year the population age-specific birth rates, age-specific death rates, and carrying capacity from distributions with means equal to the overall averages specified by the user, and with variances also specified by the user. Unfortunately, rarely do we have sufficient field data to estimate the fluctuations in birth and death rates, and in carrying capacity, for a wild population. The population would have to be monitored long enough to statistically separate sampling error from demographic variation in the number of breeders and deaths, from annual variation in the probabilities of these events. Such variation can be very important in determining the probability of extinction, yet we rarely have reasonable estimates for most populations of conservation concern. If data on annual variation are lacking, a user can try various values, or model the fate of the population in the absence of any environmental variation.

VORTEX can model catastrophes as events that occur with some specified probability and which reduce survival and reproduction for one year. A catastrophe is determined to occur if a randomly generated number between 0 and 1 is less than the probability of occurrence (i.e., a binomial process is simulated). If a catastrophe occurs, the probability of breeding is multiplied by a severity factor that is drawn from a binomial distribution with a mean equal to the severity specified by the user. Similarly, the probability of each age class surviving is multiplied by a severity factor that is drawn from a binomial distribution with a mean equal to the severity specified by the user.

The model also allows the user to supplement or harvest the population for any number of years in each simulation. The numbers of immigrants and removals are specified by age and sex. VORTEX outputs the observed rate of population growth (mean of N[t]/N[t-1]) separately for the years of supplementation/harvest and for the years without such management, and allows for reporting of extinction probabilities and population sizes at whatever time interval is desired (e.g., summary statistics can be given at 5-year intervals in a 100-year simulation).

Overall, the computer program simulates many of the complex levels of stochasticity that can affect a population. Because it is a detailed model of population dynamics, often it is not practical to examine all possible factors and all interactions that may affect a population. It is therefore incumbent upon the user to specify those parameters that can be estimated reasonably, to leave out of the model those that are thought not to have a substantial impact on the population of interest, and to explore a range of possible values for parameters that are potentially important but very imprecisely known.

A companion program, VORPLOTS, was used to produce plots of mean population size, time to extinction, and loss of gene diversity from simulation results.

EQUIPMENT REQUIRED

VORTEX requires an MS-DOS microcomputer with at least 640K of memory. Because of intensive use of floating-point mathematical calculations (primarily in numerous calls to a random number generator function), a math co-processor speeds up the program substantially. The VORPLOTS plotting program produces files in the Hewlett Packard Graphics Language (HPGL), for use on an HP plotter or equivalent. Thirteen microcomputers were provided for the workshop participants: seven Toshiba T3100 (12MHz, 80286 processor), four T3100sx (16MHz, 80386sx processor, some with math co-processors), a Terran T20 (16 MHz, 80386sx with math coprocessor), and a Toshiba T5100 (80386 with math coprocessor). An HP 7475A plotter was used for graphical presentation of results.

A Kodak Dataview EGA enabled projection of a computer display via an overhead projector onto a large screen so that all participants could observe demonstrations during initial training.

The computers were used during the daily sessions primarily for exploratory analyses with relatively few runs (100 or fewer) of a simulation; more extensive analyses were run overnight. A test with 100 runs would take from 15 minutes to 3 hours, depending on the machine used and the size of the population being simulated.

The participants varied considerably in the extent of their prior experience with computers. With assistance from those more familiar with the MS-DOS environment, interactive data entry and output was mastered quickly even by novices. Batch file input of data for overnight runs required familiarity (quickly gained) with a text editor.

THE THREATENED SPECIES EXAMINED

A summary of each of the threatened species examined in the workshop follows.

Mountain Pygmy-Possum

This species has been well studied. Its ecology has been sumarised by Calaby (1983), Broom and Mansergh (1989), Mansergh (1989), Mansergh *et al.* (1989) and Mansergh and Scotts (1990). The species is restricted to alpine and subalpine (>1 400 m altitude) rock screes and boulderfields on which *Podocarpus lawrencei* heathland is present. Diet consists of invertebrates, seeds and fruits. Breeding occurs from September–December, with litter size being 3–4. The young become independent by mid-January. Females can breed in their first year, and can live up to nine years. An unusual feature of the life history of *Burramys* is that sexes are segregated during the non-breeding season. Females occupy optimal habitat of dense *Podocarpus* habitat above 1 700 m, while males occur in less sheltered habitat between 14–1 600 m, moving into the female areas to breed. The adult population is heavily biased towards females (6F:1M) because of the high mortality experienced by males post-dispersal. The species can hibernate over winter, and store food, a feature unknown in other Australian marsupials.

The current total population is estimated to be 2 300 breeding adults, of which 80% are females. In Victoria there are three isolated sub-populations: on Mt Bogong (20 adults), Bogong High Plains (150, in six discrete areas) and Mt Higginbotham-Mt Loch (850). An additional estimated 1 300 breeding adults (sex ratio 1M:3F) occur in Kosciusko National Park in New South Wales. The species is regarded as vulnerable in Victoria and rare in New South Wales. Developments associated with skiing resorts have destroyed habitat in some areas. The central section of the most important population in Victoria occurs within a resort. The species is vulnerable to climatic changes associated with predicted global warming (Greenhouse Effect).

Leadbeater's Possum

Its biology and conservation has been well documented (Smith 1982, 1984; Lindenmayer 1989; Lindenmayer *et al.* 1990). It inhabits montane Mountain Ash *Eucalyptus regnans* forests in the central highlands region of Victoria, with a total range of about 1 000 sq. km., although critical habitat for the species is fragmented and patchy throughout this range. Leadbeater's Possum requires a forest containing large living or dead Mountain Ash with hollows in which to nest and an understorey containing Silver or Mountain Hickory Wattle *Acacia dealbata* and *A. obliquinervia* which supplies gum to supplement its main diet of invertebrates. The breeding system is monogamous and matriarchal, with colonies generally containing a breeding pair, one or two other adult males (non-breeding) and pre-dispersal age offspring. Sex ratio at birth is 1:1, but in adults it is heavily male-biased. Female offspring are ejected from the nest at sexual maturity, and so disperse earlier and have higher mortality rates than males. The average litter size is 1.6 and females can have two litters per year. Leadbeater's Possum is considered endangered. Much of the range of the species falls within State Forest destined to be harvested on a 40–80 year rotation cycle. The main concern with the species' survival is the decline of suitable hollow-bearing trees due to natural attrition and the activities of timber harvesting. The survival of Leadbeater's Possum will be heavily dependent upon sympathetic timber harvesting prescriptions.

Eastern Barred Bandicoot

Many aspects of its biology, conservation and management requirements have been documented by Clark and Seebeck (1990). The mainland population was formerly distributed over about 23 000 sq km of volcanic grassland in western Victoria. This population has now declined to about 200 or fewer individuals restricted to remnant habitat near Hamilton in western Victoria. The species is polygamous, with females capable of breeding from 3 months of age and males from 4 months of age. Gestation lasts about 12 days, with litters comprising 1–5, usually 2–3, young which remain in the pouch for about 55 days. Sex ratio of pouch young is almost 1:1. Females are capable of producing several broods per year. In spite of the very high reproductive potential, the population is believed to be declining at about 25% per annum. Juvenile mortality at dispersal from the nest is very high (>90% within the first year). The decline of the species on the Australian mainland is attributed to habitat modification from pastoral activities and predation from introduced predators including the Red Fox *Vulpes vulpes* and the Cat *Felis catus*. Other factors that may be implicated in the decline include pesticides and the disease toxoplasmosis. Habitat loss and population decline continue despite efforts to improve habitat and control feral and domestic predators, which outnumber bandicoots by more than 3 to 1.

Long-footed Potoroo

This species was first described from five specimens in 1980 (Seebeck and Johnston 1980). Ten years later its ecology is still poorly known and only 32 specimens have so far been encountered; 24 by live trapping, six by road kills and two caught in dog-traps. The species has also been recorded in 63 canid scats. Many of these records have been derived from just a few locations, and, despite extensive survey work, only 23 scattered colonies have been located. The Long-footed Potoroo has a very limited and fragmented distribution in far eastern Gippsland and southeastern New South Wales. It occurs predominantly in temperate rainforest and riparian communities with a dense understorey. Life history data for the Long-footed Potoroo are largely incomplete. Both sexes begin breeding at about two years but it is uncertain whether they are monogamous or polygamous. Litter size is one but most females probably breed more than once per annum. There is no apparent seasonality in the breeding cycle. The sex ratio at birth is believed to be 1:1 but in adults there appears to be a bias towards females. Data on sub-adult dispersal are scant but mortality is assumed to be high (50%). Size of populations and the level of migration between them is also unknown (Scotts and Seebeck 1989). The Long-footed Potoroo is regarded as endangered. The main perceived threat to its survival is predation from introduced predators. Habitat disturbance from timber harvesting operations and unsuitable fire regimes may also pose problems for its conservation. A captive colony, established from four founders in 1978 and presently comprising 13 animals, is housed at Healesville Sanctuary.

Orange-bellied Parrot

Its biology and ecology is comparatively well known (Brown and Wilson 1984; Loyn *et al.* 1986). The species is one of the rarest and most threatened birds in Australia, with a total population of 150–200 individuals. It breeds in coastal south-west Tasmania in woodlands adjoining extensive sedgelands and after breeding migrates across Bass Strait to overwinter in coastal regions of southern mainland Australia. The birds feed in a variety of coastal habitats including grasslands, saltmarsh and dune systems, showing strong preferences for particular habitats and food types in different parts of their winter range and at different times of the year. An estimated 40 breeding pairs annually produce a total of 50–70 juveniles. The Orange-bellied Parrot is considered endangered. Loss of coastal habitat for development and trapping for the aviculture trade are considered to be the primary causes of the species' past decline. Pressures for development on or adjacent to its main wintering areas and habitat alteration are now the main threats to its survival. A captive breeding program is now underway as part of a range of measures being undertaken to ensure its future survival.

Helmeted Honeyeater

Its conservation and management is described by Backhouse (1987), Smales (1989) and Woinarski and Wykes (1983). The Helmeted Honeyeater is a distinctive race of the widespread Yellow-tufted Honeyeater *Lichenostomus melanops.* Previously occurring throughout the Westernport and upper Yarra River drainages in southern Victoria, the Helmeted Honeyeater is now restricted to several small colonies along less than 10 km of streamside vegetation near the town of Yellingbo, 50 km east of Melbourne. The total known population in April 1990 was 18 breeding pairs, three unattached adults and 18 immatures. It is possible that a few other individuals exist undetected in the dense swamp and riverine habitat at Yellingbo. The Helmeted Honeyeater is considered endangered. Breeding adults defend territories for most of the year and some pairs successfully fledge up to four clutches of two young per year. Other pairs fail to fledge any young. Most young disappear over winter, presumably due to a lack of suitable unoccupied habitat into which they can disperse and establish territories. Land purchase and revegetation programs conducted over the past 20 years have consolidated and protected the remaining habitat but have not halted a steady decline in population numbers. One major cause of the shortage of habitat is that colonies of the Bell Miner *Manorina melanophrys* have established and occupied most of the suitable habitat in the reserve and aggressively exclude all other birds, including Helmeted Honeyeaters. Remedial works underway include Bell Miner management, further habitat protection and restoration and a captive breeding program. There are 12 birds in captivity at Healesville Sanctuary.

THE WORKSHOP RESULTS

Each team documented their activities and provided a preliminary report of the simulations they had completed, their conclusions, an assessment of the conduct of the workshop and the usefulness of the PVA process. Preliminary results were reported for the Mountain Pygmy-Possum by Mansergh *et al.* (1990), for Leadbeater's Possum by Thomas and Lindenmayer (1990), for the Eastern Barred Bandicoot by Patrick and Myroniuk (1990), for the Long-footed Potoroo by George (1990) and Saxon *et al.* (1990), for the Orange-bellied Parrot by Brown *et al.* (1990), and the Helmeted Honeyeater by Menkhorst *et al.* (1990). These are held at the Department of Conservation and Environment, Heidelberg. Detailed results will be published in scientific journals.

The six cases showed similar results. First, most species and populations were highly susceptible to local extinction. Any further habitat loss or fragmentation or reduction in population size and density would result in rapid extinction. Second, in all cases, more field data would have been helpful, especially for species like the Long-footed Potoroo. Third, management options to stave off extinction were identified and results simulated. Options included strict habitat protection, enhancement of existing habitat or restoration of lost habitat, captive breeding, and reintroduction of animals to existing habitat patches in which the species has become extinct in recent decades or to newly created habitat. Various combinations of management strategies were recommended for future management. Fourth, the simulations demonstrated that if proactive conservation management had been undertaken even five or ten years ago when populations and habitats were considerably larger, the task of present day managers would be much more tractable. And fifth, improved conservation management for all six species is expected to result from the PVA exercise and subsequent on-ground management.

Three cases are presented here to illustrate these conclusions:

The Mountain Pygmy-possum exists in a number of discrete populations isolated on mountain tops (Mansergh *et al.* 1990). Seven populations, ranging from 20–950 individuals (representing the situation in the wild) were modelled. High probabilities of extinction were observed in all small ($n=<150$) populations at 25 and 50 years (which could account for the absence of the species from apparently suitable habitat within its range). The larger populations had a decreased likelihood of extinction. When modelled with a small but steady decrease in carrying capacity (1% per annum), the probability of extinction increased greatly (to 45% in the case of the largest Victorian population of 850 individuals, over 50 years). Disturbance to habitat and further fragmentation of populations would increase the likelihood of extinction.

Wild and captive populations of the Eastern Barred Bandicoot were simulated (Patrick and Myroniuk 1990). Modelling the wild population using available data without any change to current management indicated a 100% probability of extinction within 25 years, with a mean time to extinction of 7.2 years (±2.1). Doubling the carrying capacity and leaving mortality unchanged had negligible impact on the probability of extinction and increased the mean time to extinction by only two years. Doubling the carrying capacity, reducing mortality by 30% and supplementing the wild population with the liberation of captive-bred animals greatly enhanced prospects for survival of the wild population. Under this scenario the probability of extinction was reduced to 0% over 25 years with a mean final population size of close to the carrying capacity of 300 animals. Modelling the existing and proposed captive populations indicated a variety of scenarios. The existing captive population of 16 pairs has an extinction probability of 83% over 25 years, with a mean time to extinction of 21.5 years. Doubling the number of adult pairs decreased the extinction probability to 0% but the surviving population had low genetic variability, and there is little potential to harvest juveniles for release into the wild. Increasing the captive population to 62 adult pairs increased genetic variability and the potential to harvest offspring for release to the wild without jeopardising the captive population. Maintaining a captive population of 62 adult pairs (in two groups at separate locations to avoid catastrophe but managed as one population) and establishing two semi-captive populations with a capacity for 400 animals gave the best prospects for long-term survival, maintenance of genetic variability, and production of sufficient offspring to consider reintroductions to suitable habitat within their former range. The exercise highlighted the need for a combination of management actions, rather than any single action, to prevent the almost certain extinction of the wild population under the existing management regime. Reduction of mortality by predator control and traffic management is essential for the survival of the Eastern Barred Bandicoot. Captive management will be an important part of the recovery program, but with a more intensive program than that currently underway.

Populations of the Orange-bellied Parrot were modelled using the current carrying capacity (150), a reduced carrying capacity (50) and an increased carrying capacity (500). Simulations involving varying mortality, and the effects of capture from, and supplementation of, the wild population were run for all carrying capacities. Simulating the existing population using current data and management regimes indicated that the species would remain extant over the next 50 years at least, and stood a good chance of surviving for 100 years. Reducing the carrying capacity to 50 under current conditions did not increase the probability of extinction over 50 years, although genetic variability was greatly diminished. Increasing the carrying capacity to 500 birds further removed the prospects of extinction and greatly increased the genetic variability of the population. When modelled with an increased juvenile mortality (75% cf 50%) the population with the reduced carrying capacity showed a 70% probability of extinction within 50 years, while the current and increased carrying capacity populations showed extinction probabilities of 20% in that time. Imposing a capture and release captive breeding program on the populations only slightly decreased the extinction probability of the reduced carrying capacity, high mortality population, but greatly improved heterozygosity in the reduced carrying capacity, current mortality population. No extinctions occurred in the current and increased carrying capacity populations even at the high mortality levels, when simulated with supplementation from a captive breeding program. The simulations indicate several points. Juvenile mortality is of great significance to the health of the population. Any increase above the present rate of 50% greatly increases the probability of extinction, even with an enhanced habitat carrying capacity. The captive breeding program is an important back-up to the wild population, and will be extremely valuable if the wild population declines from present levels.

CONCLUSION

The PVA workshop proved a useful way of learning a new technique for threatened species management and conservation. PVA's were applied to six species allowing a critical, quantitative analysis of extinction probabilities, as well as exploring management options to prevent species loss. PVA results will be used in forthcoming management plans and management actions in the field directed towards restoring these species to a status from which they will be relatively immune to extinction from random processes. In the future, it can be expected that PVAs will be carried out on additional endangered species to help manage their recovery. Although VORTEX is a comparatively detailed simulation, it still remains a simplistic model of the dynamics of real populations. This limitation must be realized when managers are assessing simulation outcomes. PVA using VORTEX is a powerful tool to aid species recovery programs.

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REFERENCES

BACKHOUSE, G. N., 1987. Management of remnant habitat for conservation of the Helmeted Honeyeater *Lichenostomus melanops cassidix.* Pp. 287–94 in *Nature Conservation: The Role of Remnants of Native Vegetation* ed by D. A. Saunders, G. W. Arnold, A. A. Burbidge and A. J. M. Hopkins. Surrey Beatty & Sons: Sydney.

BROOME, L. AND MANSERGH, I., 1989. The Mountain Pygmy-possum *(Burramys parvus)* Broom: an alpine endemic. Pp. 241–64 in *Proceedings of the first Fenner Conference: Scientific significance of the Australian Alps.* Australian Academy of Science 13–15 September 1988: Canberra.

BROWN, P. B. AND WILSON, R. I., 1981. Orange-bellied Parrot Recovery Plan. NPWS, Tasmania, June 1984. 125 pp.

BROWN, P., LOYN, R. AND STARKS, J., 1990. A population viability assessment of the Orange-bellied Parrot *Neophema chrysogaster.* Unpublished report from PVA workshop, DCE: 7pp.

BRUSSARD, P. F., 1985. Minimum viable populations: how many are too few? *Restoration and Management Notes* **3**(l): 21–25.

CALABY, J. H., 1983. Mountain Pygmy-Possum. Pp. 168–69 in *Complete Book of Australian Mammals* ed by R. Strahan. Angus & Robertson Publisher: Sydney.

CLARK, T. W. AND SEEBECK, J. H. (eds), 1990. Management and conservation of small populations. Chicago Zoological Society: Brookfield, Ilinois. 292 pp.

GEORGE, G. G., 1990. Report on a population viability assessment for the Long-footed Potoroo captive breeding programme. Unpublished report from PVA workshop, DCE: 9 pp.

GILPIN, M., 1989. Population viability analysis. *Endangered Species UPDATE* **6**(10): 15–18.

GRIER, J., 1980a. Ecology: A simulation model for small populations of animals. *Creative Computing* **6:** 116–21.

GRIER, J. W., 1980b. Modelling approaches to bald eagle population dynamics. *Wildlife Society Bulletin* **8:** 316–22.

GRIER, J. W. AND BARCLAY, J. H., 1988. Dynamics of founder populations established by reintroduction. Pp. 689–701 in *Peregrine Falcon Populations: Their Management and Recovery* ed by T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White. The Peregrine Fund: Boise, Idaho.

LACY, R. C., FLESNESS, N. R. AND SEAL, U. S., 1989. Puerto Rican parrot population viability analysis. Report to the U.S. Fish and Wildlife Service. Captive Breeding Specialist Group, Species Survival Commission, IUCN: Apple Valley, Minnesota. 129 pp.

LACY, R. C. AND CLARK, T. W., 1990. Population viability assessment of the Eastern Barred Bandicoot in Victoria. Pp. 131–46 in *The Management and Conservation of Small Populations* ed by T. W. Clark and J. H. Seebeck. Chicago Zoological Society: Brookfield, Illinois.

LINDENMAYER, D. B., 1989. The ecology and habitat requirements of Leadbeater's Possum. Ph.D. Thesis, Australian National University: Canberra. 438 pp.

LINDENMAYER, D. B., CUNNINGHAM, R. B., TANTON, M. T., SMITH, A. P. AND NIX, H. A., 1990. The conservation of arboreal marsupials in the montane ash forests of the central highlands of Victoria, south-east Australia. 2. The loss of trees with hollows and its implications for the conservation of Leadbeater's Possum *Gymnobelideus leadbeateri* McCoy (Marsupialia: Petauridae). *Biol. Conserv.* **54.** (in press).

LOYN, R. H., LANE, B. A., CHANDLER, C. AND CARR, G. W., 1986. Ecology of Orange-bellied Parrots *Neophema chrysogaster* at their main remnant wintering site. *Emu* **86**(4): 195–206.

MANSERGH, I. M., 1989. The ecology and conservation of the Mountain Pygmy-possum *(Burramys parvus)* in Victoria with comparisons to populations in New South Wales. Ph.D. Thesis, LaTrobe University: Victoria. 342 pp.

MANSERGH, I. M., KELLY, P. AND SCOTTS, D. J., 1989. Management strategy and guidelines for the conservation of the Mountain Pygmy-possum *(Burramys parvus)* in Victoria. Arthur Rylah Institute for Environmental. Research. Technical Report Series. No. **66:** 1–60.

MANSERGH, I. M. AND SCOTTS, D. J., 1990. Aspects of the ecology of the Mountain Pygmy-possum *Burramys parvus* (Broom) (Marsupialia: Burramyidae) in alpine Victoria. *Aust. Mammal.* (In press).

MANSERGH, I., SCOTTS, D. AND EARL, G., 1990. A preliminary population viability assessment of the Mountain Pigmy-possum *Burramys parvus.* Unpublished report from PVA workshop, DCE: 4 pp.

MENKHORST, P., MURRAY, N., SMALES, I. AND FRANKLIN, D., 1990. Helmeted Honeyeater — preliminary population viability assessment. Unpublished report from PVA workshop, DCE: 7 pp.

PATRICK, C. AND MYRONIUK, P., 1990. Preliminary population viability assessment of the Eastern Barred Bandicoot: Selected wild and captive population scenarios. Unpublished report from PVA workshop, DCE: 7 pp.

SAMSON, F. B. 1985. Minimum viable populations — a review. *Natural Areas Journal* **3**(3): 15–23.

SAXON, M. J., BENNET, A. F., SEEBECK, J. H. AND PASCOE, C. G., 1990. Using population viability assessment to investigate the extinction risks for populations of the Long-footed Potoroo, *Potorous longipes.* Unpublished report from PVA workshop, DCE: 15 pp.

SEAL, U. S. AND LACY, R. C., 1989. Florida panther population viability analysis. Report to the U.S. Fish and Wildlife Service. Captive Breeding Specialist Group, Species Survival Commission, IUCN: Apple Valley, Minnesota. 138 pp.

SEEBECK, J. H. AND JOHNSON, P. G., 1980. *Potorous longipes* (Marsupialia: Macropodidae), a new species from eastern Victoria. *Aust. J. Zool.* **28:** 119–34.

SCOTTS, D. AND SEEBECK, J. H., 1989. Ecology of *Potorous longipes* (Marsupialia: Potoroidae); and preliminary recommendations for management of its habitat in Victoria. Arthur Rylah Institute for Environmental Research. Technical Report Series. No. **62:** 1–129.

SHAFFER, M. L., 1981. Minimum population sizes for species conservation. *BioScience* **31**(2)**:** 131–34.

SMALES, I., 1988. The status of the Helmeted Honeyeater *Lichenostomus melanops cassidix* (Gould) with recommendations for its continued conservation. Report to Department of Conservation and Environment: Victoria. 31 pp.

SMITH, A. P., 1982. Leadbeater's Possum and its management. Pp. 129–45 in *Species at Risk: Research in Australia* ed by R. H. Groves and W. D. L. Ride. Australian Academy of Science: Canberra.

SMITH, A. P., 1984 Demographic consequences of reproduction, dispersal and social interaction in a population of Leadbeater's Possum *(Gymnobelideus leadbeateri).* Pp. 359–73 in *Possums and Gliders* ed by A. P. Smith and I. D. Hume. Australian Mammal Society: Sydney.

SOULÉ, M. E., 1989. Risk analysis for the Concho Water Snake. *Endangered Species UPDATE* **6**(10)**:** 19–25.

THOMAS, V. AND LINDENMAYER, D., 1990. A population viability analysis of Leadbeater's Possum, *Gymnobelideus leadbeateri* McCoy. Unpublished report from PVA workshop, DCE: 16 pp.

WOINARSKI, J. C. Z. AND WYKES, B. J., 1983. Decline and extinction of the Helmeted Honeyeater at Cardinia Creek. *Biol. Conserv.* **27:** 7–-21.

From the Secretary's Desk

Members are reminded that Annual Subscriptions are now due — your renewal form **is included** in this copy of the journal.

As ALL the work done from the Society's office is carried out by volunteers, I would like to place on record my deep appreciation of all the time they give — especially our Assistant Treasurer, Betty Bull, without whom I certainly could not cope! Our thanks to John Raison are expressed elsewhere, in the obituary, but I would like to add my personal appreciation for his untiring patience as he tried to initiate us to the complexities of computers — without John the new system would still be a pipe dream — his cheery visits to the Rooms to cope with our constantly repeated questions were always welcome — a great person.

I have to be overseas for two months in August–October: If anyone has a little time on a Tuesday when they would be willing to give Betty a hand with routine chores in the Rooms, could they please give us a call (preferably on Tuesdays between noon and 4.30 p.m.) on 969 7336, it would be great to hear.

Marianne Cochrane
Hon. Secretary

Mammal Section Talks for 1991

Mark the following dates on your calendars, but check with Murray Ellis on 587 5519 for any last minute changes to time or speakers.

Jun. 25	**Tracey Rogers** Vocal behaviour in Leopard Seals at Taronga Zoo.
Jul. 23	**Ian Hume** Nutritional ecology of North American Rodents.
Aug. 27	**Christine Hopkins** Native mammals in Australasian Zoos; the present and the future.
Sep. 24	**Tania Bubela** Social behaviour of the fox in sub-alpine Australia.
Oct. 22	**Andrew Crockenburger** Lactation in Koalas.
Nov. 26	**Chris Allen** The diet of the Yellow-footed Rock-wallaby